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WHEN TO PLANT BITTERBRUSH-

SPRING OR FALL?

R. L. HUBBARD & H. R. SANDERSON

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WHEN TO PLANT BITTERBRUSH—SPRING OR FALL?

By
Richard L. Hubbard and H. Reed Sanderson

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U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION
BERKELEY, CALIFORNIA

The results of fall vs. spring comparisons from each study are discussed separately but the conclusions drawn are based on the results of all studies.

Depth of Planting

Emergence from various planting depths was tested from 1953 through 1957 inside deer-livestock exclosures at two experimental areas: Flukey Spring in Modoc County and Doyle in Lassen County. The Flukey Spring area is on the winter range of the California-Oregon interstate deer herd; the Doyle area is on the winter range of the Lassen-Washoe deer herd. The soil at Flukey Spring is a slightly gravelly loam of basalt origin. Annual precipitation averages 12 to 14 inches. The soil at Doyle is a gravelly, coarse, sandy loam of granitic origin, and the annual precipitation averages 9.5 inches.

Seeds were spot planted at $\frac{1}{2}$-inch interval depths with 5 seeds in each spot. The first year, 50 seeds were planted at depths ranging from 0--seeds placed on the soil surface--to 2 inches; in the remaining 3 years, 500 seeds were planted at depths ranging from 0 to 4 inches. Most of the emergence was from seed planted $\frac{1}{2}$ to 2 inches deep and these are the depths considered in this paper. Soil moisture was recorded weekly at the $1\frac{1}{2}$ inch depth from 1954 through 1957 with fiberglas soil moisture units (Colman, 1947).

At Flukey Spring, average emergence from all depths was best with spring planting in 4 of the 5 study years (table 1). Spring-planted seed tended to emerge from a wider range of depths than fall-planted seed. The difference was more clearcut in some years than in others. In 1956 and 1957 emergence from fall-planted seed at the $\frac{1}{2}$ inch depth was excellent, but emergence from seed planted deeper than 1 inch was poor. In contrast, emergence from spring-planted seed was good from $\frac{1}{2}$, 1, and $1\frac{1}{2}$ inch depths. Even at the 2 inch depth, where emergence from the fall planting was zero in both years, spring-planted seed gave fair emergence. This tendency has practical importance since it is impossible to get perfect depth control when drilling seed. Therefore, the wider the range of planting depths which produce seedlings, the better the chance for a successful drill seeding.

Seeds and seedlings must have sufficient soil moisture during the critical germination and emergence periods if they are to produce and survive. Soil moisture at Flukey Spring was adequate in all years during these periods, which usually end about the second week in May for spring plantings and about a month earlier for fall plantings. This was true even in 1955 when fall planting proved better than spring. Soil temperatures were higher than normal in March and April 1955. This condition, coupled with the adequate soil moisture, should have resulted in good emergence from spring planting.

Damping-off fungi may have been responsible for the poor showing of the 1955 spring planting. While damping-off was not definitely diagnosed, it is known that high soil temperatures and moist soil are very

WHEN TO PLANT BITTERBRUSH—SPRING OR FALL?[1/]

By
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Different results from different parts of the country have caused land managers to ask themselves "Should I plant bitterbrush in the spring or in the fall?" In Idaho and Washington fall plantings have proved best (Holmgren and Basile, 1959; Brown and Martinsen, 1959). In northeastern California, spring planting has the edge (Hubbard, et al., 1959). This difference is apparently due to differences in site and climate.

Is there one best time to plant? Comparative fall-spring bitterbrush plantings were made in seven growing seasons on various sites in northeastern California. In the majority of cases, spring planting gave better results. But this doesn't mean that we should always plant in the spring. Far from it. Because of site variations, no single prescription can be written to cover all bitterbrush planting situations. This applies not only to time of planting but also to planting depth, site preparation, seed source, and other steps in the seeding job. Each planting prescription must be tailor-made for the particular situation. This paper reports results of comparative plantings and describes the conditions under which it is best to plant in the fall and those under which it is best to plant in the spring.

Bitterbrush has a dormant seed. The dormancy of fall-planted seed is broken naturally while the seed over-winters in the soil. But spring-planted seed must either be stratified in a moist media at temperatures between 32 and 41 degrees F. for a 5- to 8-week period (Hormay, 1943), or be treated with thiourea, a chemical which artificially breaks the seed dormancy (Pearson, 1957; Hubbard and Pearson, 1958). Except for depth of planting trials in 1953 and 1954, all spring plantings reported here were made with thiourea-treated seed. The seed used in 1953 and 1954 was stratified in the laboratory.

The spring-fall comparisons are part of three different studies, each aimed at getting answers to different problems as well as comparing fall and spring planting. In addition to the spring-fall comparison these studies tested:

1. The proper depth at which to plant bitterbrush seed to obtain the best emergence.
2. Seedling growth and survival on different sites.
3. Application of research findings to field scale plantings.

1/ Contribution from cooperative investigations between the Pacific Southwest Forest and Range Experiment Station and the California Department of Fish and Game. Work was done under Federal Aid in Wildlife Restoration Act, Pittman-Robertson Research Project W51R entitled "Game Range Restoration."

favorable conditions for the growth of certain of these fungi (Wagle, 1958; Toumey and Korstian, 1916; Baxter, 1943). Symptoms of damping-off were present on 21 percent of emerged seedlings on fall-planted plots in 1955 but on none in 1956 and on only 2.5 percent in 1957. These symptoms showed up about the time emergence should have begun on the spring planting. Chances are that damping-off killed most germinating spring-planted seedlings because few emerged before May 2--several weeks later than usual.

The picture at Doyle was rather different. Here, spring planting was best in 1953 and 1956; fall planting in 1954 and 1955; and spring and fall plantings were equally good in 1957. Doyle is a much drier site than Flukey--it receives less precipitation and the lighter soil loses moisture faster. In 1954 and 1955, soil moisture dropped markedly at the $1\frac{1}{2}$ inch depth during the first 3 weeks of April--the period when maximum emergence of spring-planted seed usually occurs at Doyle. Emergence from fall planting is usually complete by the first week in April, so this drying had little effect on the emergence of fall-planted seed. No such soil moisture drop occurred in 1956 or 1957.

No evidence of damping-off was found at Doyle. The only factor definitely diagnosed as affecting emergence--other than soil moisture--was insect larvae. Cutworms and wireworms killed 87 percent of the seedlings emerging in 1955 from the fall planting (Hubbard, 1956). Besides cutting off emerged seedlings, cutworms also fed on germinating seed. Insecticide, applied after the damage to the fall planting was noticed, gave some protection to the later emerging spring planting.

Seedling mortality did not seem to be consistently related to time of planting at either Flukey Spring or Doyle. At Flukey Spring, the only appreciable difference was in 1954, when 78 percent of the seedlings died on the spring planting, and 66 percent on the fall planting (table 2). In the other three seasons for which data are available, mortality differences were minor.

At Doyle, mortality was more variable. Many more seedlings died in 1954 and 1956 on the fall plantings than on the spring plantings. As already mentioned, the extreme difference in 1956 was largely due to cutworms and wireworms. Although not as well documented, insect larvae were probably also responsible for much of the difference in 1954. Mortality differences in the other two years are too small to be of practical importance.

At both areas there was a big difference in mortality from year to year. At Flukey Spring the range was from 8 to 78 percent; at Doyle from 6 to 98 percent. These seedlings were not grazed. Mortality differed because of weather, attacks by insects, soil fungi, and probably many other factors not yet diagnosed. Some of these decimating factors can be controlled; others cannot.

Time of planting did affect seedling size. Seedling height was measured at the end of the first growing season at both Flukey Spring

and Doyle in 1955 and 1957. Seedlings from fall plantings were larger than those from spring plantings at both areas in both years (table 3). Height differences averaged 1.4 inches in 1955 and 1.5 inches in 1957 at Flukey Spring. At Doyle, the difference in both years averaged 1.8 inches. This close agreement between years suggests that the prime reason for the difference was the earlier growth start of the seedlings from the fall plantings. Despite the somewhat smaller size, the seedlings from the spring plantings were healthy, had well developed root systems, and were capable of competing and growing successfully in following years.

Site Adaptability

Bitterbrush growth, survival, and spring vs. fall planting were studied on a variety of sites in 1959 and 1960. We purposely selected study plots with different precipitation and soil types. By precipitation classes, the locations and soil descriptions of these plots are:

1. 15 to 20 inches annual precipitation

   Meadow View, Lassen County--loam
   Lava Beds National Monument--slightly gravelly loam
   Lava Beds National Monument--coarse pumice
   Sheepwell burn, Siskiyou County--slightly gravelly loam
   Bolam burn, Siskiyou County--fine pumice

2. 10 to 15 inches annual precipitation

   Mears burn, Modoc County--slightly gravelly loam

3. 8 to 10 inches annual precipitation

   Casuse Mountain, Modoc County--lava ash soil, gravelly sandy loam
   Doyle, Lassen County--gravelly, coarse sandy loam

4. Less than 8 inches annual precipitation

   Sage Flat, Lassen County--gravelly, coarse sandy loam

One hundred seed spots containing 5 seeds each were planted during the fall in 1958 and 1959 and in the spring of 1959 and 1960 at each site. Both 1959 and 1960 were extremely dry years. Precipitation in the 1959 hydrologic year (October 1 to September 30) was 59 percent of normal at Tulelake and 70 percent at Alturas. In the 1960 hydrologic year, precipitation was 81 percent of normal at Tulelake and 74 percent at Alturas.

Spring plantings made poor showings in 1959. Fall planting proved best on every one of the nine test sites where there was some emergence (table 4). No seedlings emerged from either fall or spring planting at Casuse Mountain. In 1960, emergence from the spring planting equaled or

exceeded that from the fall planting at 4 of the 8 sites where emergence occurred. Casuse Mountain again failed to produce from either fall or spring planting. Precipitation was low on this site and the light textured soil lost moisture rapidly.

Although there were differences in survival, no trend was established favoring either spring or fall planting (table 5). Because only 500 seeds were used in each planting and because of the low emergence from some, many of the survival percentages are based on small numbers and, therefore, may not be reliable.

These results suggest that even on sites suitable for spring planting in normal rainfall years, fall planting is better in extremely dry years than spring planting.

Pilot Seedings

The proof of research findings is how well they stand up in field application. From 1954 through 1961, 28 pilot drill plantings, ranging in size from 1 to 60 acres, were made to further test research results. Experiment Station personnel planted some of these, while California Department of Fish and Game and National Forest personnel planted others. The results from pilot plantings made through 1958 have been reported (Hubbard, et al., 1959) but are reviewed here, along with reports of more recent plantings, to add information on spring-fall planting. From 1953 to 1957, 6 to 8 pounds of seed were planted per acre. From 1958 to 1961 the rate was 3 pounds per acre except for a 6-pound rate in 1960 at Flukey Spring.

Direct spring-fall comparisons were made near Red Rock and Hallelujah Junction. These locations were about 15 and 20 miles south of Doyle, California. The sites were similar, with an average precipitation of 8 to 10 inches and a light-textured soil with low water holding capacity. At best, they were borderline bitterbrush sites because of dryness and high soil pH in spots. Four plots were planted in the fall of 1954 and three in the spring of 1955. About 1,100 seedlings per acre emerged on the best spring planting; 1,000 on the best fall planting. But all of the fall plantings far surpassed the other two spring plantings. Precipitation at Doyle, the nearest weather station, was 62 percent of normal in 1955. In addition to the low annual rainfall, a nearly complete lack of moisture in April made conditions very severe. Perhaps in a wetter year, spring planting would have made a better showing. But this site is, at best, borderline for spring planting and perhaps for any kind of bitterbrush planting.

In 1956, a fall planting near the Doyle exclosure was a complete failure. A nearby spring planting produced a stand of 2,000 plants per acre at the end of the first growing season. This site was not as dry as the Red Rock and Hallelujah Junction sites, but still must be classed as a dry bitterbrush site. Precipitation at Doyle in the 1956 hydrologic year was nearly twice normal, but nearly two-thirds of the total fell during December. March and May were very dry, but April was well above normal.

Soil moisture at the nearby experimental area was adequate for germination during the critical period. The difference between the fall and spring pilot plantings was greater than would have been expected from results the same year on the depth-of-planting study at Doyle, in which emergence was 10.8 percent from fall-planted seed and 22.0 percent from spring-planted. Damage by cutworms and wireworms was undoubtedly at least partially responsible for failure of the fall pilot planting.

A fall planting at Dobie Flat, Modoc County, in 1956 failed completely, but a spring planting produced 6,500 seedlings per acre. Dobie Flat is not a good bitterbrush site because of poor drainage and high soil pH. The soil is heavy and retains moisture well but tends to crust and prevent seedling emergence. Severe crusting occurred on the fall planting and was probably responsible for its failure. Harrowing before spring planting broke this crust and permitted good emergence.

At Mears, a site similar to the Flukey Spring Experimental area, 2 fall plantings produced 1,700 to 2,300 seedlings per acre in 1956. Comparable spring plantings produced 5,200 and 8,600 seedlings per acre. This is better than a three-fold increase from spring planting. But on the Flukey Spring depth-of-planting study in the same year, the increase was only a little over $1\frac{1}{2}$ times. This "larger than expected" spread on drill plantings seems to be general. The reasons are incompletely understood. Fall-planted seed is, of course, exposed in the field considerably longer than is spring-planted seed. Rodents, frost heaving of the seed to deeper or shallower depths, insects, and probably other decimating factors have a longer period to act. Probably the tendency of spring-planted seed to emerge from deeper depths is also important. Whatever the reasons, where spring planting has proved best the spread between fall and spring planting is usually greater on drill plantings than on smaller experimental plantings.

A spring, 1960 drill planting near Flukey Spring produced an estimated 3,000 to 5,000 seedlings per acre. The site was very similar to the site-adaptability plot at Mears, where the 1960 spring planting was a complete failure--owing in part to soil crusting. This was the only instance of serious crusting encountered on a spring planting. The plot was wet when planted, and the soil may have been compacted during hand planting.

Spring planting works in dry years if the soil is heavy enough to retain moisture well. In addition to the plantings near Flukey Spring, 60 acres were planted near Saddle Blanket Flat in Modoc County. This site was much drier than Flukey Spring but had a relatively heavy loam soil. Despite the dry site and dry year, emergence averaged about 1,200 seedlings per acre. The seeding rate used was 3 pounds per acre compared to 6 pounds at Flukey Spring. A 10-acre 1960 spring planting on a lighter and drier soil near the Doyle Experimental area was a complete failure. The area was plowed, then dragged with railroad irons and packed with a cultipacker. A lag of a day or so between the plowing and the other operations increased the drying rate. On sites where moisture is critical such increased drying cannot be tolerated.

Two pilot plantings emphasize the importance of precipitation during the critical germination and emergence periods. Both plantings were done in 1961: one of 10 acres near the Doyle Experimental area and another of about 30 acres near Cornell Rims, Modoc County--an area similar to the Saddle Blanket Flat site planted in 1960. Much of the germinating seed dried and died during April when precipitation was 67 percent of normal at Doyle and only 18 percent at Tulelake, the closest weather station to the Cornell Rim seeding. Seed dug up in May showed signs of having germinated, dried, and then rotted. However, enough non-germinated seed remained to germinate after May rains and stock the Cornell Rim area with about 1,000 seedlings per acre and the Doyle area with about 350 per acre.

Conclusions and Summary

"Should bitterbrush be planted in the spring or in the fall?" The answer varies with site and rainfall. Results of spring-fall planting comparisons in northeastern California, on a variety of sites and spread over 7-different growing seasons, show that spring planting is superior to fall planting on many sites.

For planting success the soil at planting depth must remain moist during germination and emergence. Emergence is usually 3 to 4 weeks later from spring planting than from fall. Fall planted seed is in the ground ready to germinate as soon as the soil warms up. This means that the soil must remain moist longer for spring plantings to succeed. Either, or both, of two conditions must be met to provide this longer moist period. Precipitation must be adequate and well distributed during the critical period and the soil must retain moisture well. Loam soils as a rule retain moisture rather well; coarse sands lose moisture rapidly.

Fall planting may be best in very dry years on sites normally adapted to spring planting. With present weather forecasting, this point may be academic since we can classify sites only on the basis of average precipitation. But with continued advances in long-range forecasting, the land manager, may, in time, have enough information to foresee the best planting schedule. If fall planting is necessary, increases in seeding rate and, consequently, costs may be necessary. Perhaps the decision should be not to plant in dry years.

On normally dry sites, spring planting will usually fail. Here, the only possibility is to plant in the fall.

The reasons for the superiority of spring planting are incompletely understood. Spring-planted seed is exposed for a shorter period of time. Rodents have less time to dig up the seed and also rodent numbers are at their seasonal low. The heaviest rodent use of bitterbrush seed seems to be after the seed starts to germinate. Fall-planted bitterbrush seed germinates earlier than the seed of many of the herbaceous species. Perhaps the lack of other food attracts the rodents to the early germinating bitterbrush seed. Lack of food may also be responsible

for heavy insect attacks. Frost action may replant fall-planted seed at either too shallow or too deep depths. Emergence of spring-planted seed from deeper depths may also help explain the superiority of spring planting. Whatever the reasons, our experimental results have established the superiority of spring planting on the moister sites.

Seedlings from spring plantings are consistently smaller than those from fall plantings. But no more of them die. Despite their somewhat smaller size, the seedlings from spring plantings are healthy, have well developed root systems, and are capable of competing and growing successfully in following years.

Spring planting is a tightly scheduled job. The seeding crew must start just as soon as the ground thaws and weather permits. The job must be completed within 2 or 3 weeks. Fall planting can be spread out over several months. Despite the operational difficulties, we recommend spring planting on suitable sites. Results from spring planting have been enough better to fully justify this recommendation. We do not recommend spring planting on sites where soil moisture is inadequate for germination. Here, fall planting is the only possibility.

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Appendix

Table 1.--Emergence from fall and spring planted seed from various planting depths

Growing season and planting time	Percent emergence when planting depth in inches was-- 1/2	1	$1\frac{1}{2}$	2	Average
FLUKEY SPRING					
1953					
Fall-planted	12	14	8	18	13.0
Spring-planted	32	44	52	64	48.0
1954					
Fall-planted	14	28	21	4	16.8
Spring-planted	43	56	19	4	30.5
1955					
Fall-planted	44	38	8	0	22.5
Spring-planted	16	17	9	6	12.0
1956					
Fall-planted	52	14	8	0	18.5
Spring-planted	29	47	32	11	29.8
1957					
Fall-planted	61	51	5	0	29.2
Spring-planted	54	57	45	11	41.8
DOYLE					
1953					
Fall-planted	16	20	46	38	30.0
Spring-planted	30	42	50	26	37.0
1954					
Fall-planted	23	36	12	3	18.5
Spring-planted	22	17	14	3	14.0
1955					
Fall-planted	44	57	16	(1/)	29.2
Spring-planted	8	16	5	(1/)	7.2
1956					
Fall-planted	38	5	0	0	10.8
Spring-planted	30	33	20	5	22.0
1957					
Fall-planted	72	60	30	2	41.0
Spring-planted	39	58	50	12	39.8

1/ Trace.

Table 2.--Mortality of seedlings from fall and spring plantings made for the depth of planting study

Growing season	Experimental area and time of planting: Flukey Spring: Fall planting	Flukey Spring: Spring planting	Doyle: Fall planting	Doyle: Spring planting
	Percent			
1954	65.5	77.7	79.2	56.1
1955	65.9	65.6	47.8	50.0
1956	8.1	7.9	98.2	40.7
1957	10.7	8.4	5.9	12.8

Table 3.--Average height of bitterbrush seedlings on the depth of planting study at the end of their first growing season

Growing season	Experimental area and time of planting: Flukey Spring: Fall planting	Flukey Spring: Spring planting	Doyle: Fall planting	Doyle: Spring planting
	Inches			
1955	7.35	5.92	4.66	3.18
1957	5.88	4.09	5.09	3.25

Table 4.--Emergence from fall and spring plantings made for the site adaptability study

Experimental area	Growing season and time of planting: 1959: Fall planting	1959: Spring planting	1960: Fall planting	1960: Spring planting
	Percent			
Modoc Lava Beds	13	(1/)	5	3
Outside Lava Beds	27	12	8	4
Sheepwell Burn	23	13	8	15
Bolam Burn	27	(1/)	24	18
Casuse Mountain	0	0	0	0
Mears Burn	11	1	8	0
Doyle	10	4	5	7
Meadow View	37	1	19	38
Sage Flat	14	0	3	4

1/ Trace.

Table 5.--Mortality of seedlings from fall and spring plantings made for the site adaptability study

Experimental area	Growing season and time of planting:			
	1959		1960	
	Fall planting	Spring planting	Fall planting	Spring planting
	Percent			
Modoc Lava Beds	97	100	54	62
Outside Lava Beds	47	69	92	45
Sheepwell Burn	67	82	8	12
Bolam Burn	18	0	32	57
Casuse Mountain	--	--	--	--
Mears Burn	70	0	49	--
Doyle	27	17	23	54
Meadow View	45	17	37	31
Sage Flat	66	--	94	86

Table 6.--Cumulative precipitation at 4 weather stations in northeastern California, 1953-1961, and long-time means

Area and year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.
	Inches											
Alturas												
1953	.17	.97	3.60	5.69	6.64	7.82	8.67	11.92	14.02	14.02	14.57	14.62
1954	.70	2.61	3.81	5.29	6.40	9.16	10.28	10.63	12.30	12.90	13.23	13.28
1955	.40	1.50	2.90	3.57	4.42	5.22	6.87	7.32	7.75	8.14	8.14	8.79
1956	.05	1.66	5.66	8.88	10.07	10.47	11.40	12.67	13.57	15.06	15.16	15.82
1957	2.77	2.97	4.33	5.28	7.27	9.82	10.98	13.13	13.23	13.23	13.23	14.18
1958	2.40	4.83	6.59	8.44	10.83	12.18	12.65	13.70	16.45	17.30	17.70	18.19
1959	.85	1.69	2.78	3.89	5.13	5.31	5.51	7.27	7.63	7.72	8.36	9.02
1960	.36	.36	1.03	2.77	5.01	6.74	7.73	8.89	8.89	9.26	9.30	9.50
1961	.18	2.98	3.49	3.59	5.26	6.56	6.74	--	--	--	--	--
46 year mean	1.02	2.38	4.12	5.77	7.15	8.54	9.63	10.91	11.99	12.26	12.48	12.88
Doyle												
1953	.00	.66	2.50	4.81	4.81	5.73	5.87	6.99	7.58	7.58	8.00	8.00
1954	.27	.57	.77	2.11	3.74	4.99	5.02	5.02	5.41	5.43	5.43	5.43
1955	.00	1.21	2.98	3.66	3.91	4.26	4.26	4.82	4.89	5.12	5.12	6.02
1956	.62	.91	11.99	16.23	16.75	16.80	18.05	18.11	1/ 18.11	--	--	--
1957	--	--	--	--	--	--	--	--	--	--	--	--
1958	--	--	--	--	--	--	--	--	--	--	--	--
1959	--	--	--	--	--	--	--	--	--	(1/)	.11	.67
1960	.02	.02	.55	1.63	4.82	5.67	5.91	6.24	6.24	6.71	6.71	6.85
1961	.13	1.50	2.47	3.17	3.93	5.00	5.39	--	--	--	--	--
33 year mean	.81	2.06	3.50	4.82	6.28	7.33	7.91	8.49	8.98	9.15	9.27	9.55
Tulelake												
1953	.05	.51	2.58	4.14	5.19	6.33	7.06	9.33	10.70	10.70	12.24	12.35
1954	1.40	3.63	4.82	6.02	6.94	8.29	8.69	8.97	10.73	10.73	10.96	11.05
1955	.16	1.05	2.19	2.48	2.87	3.62	4.26	4.28	4.70	4.95	4.99	5.88
1956	.38	2.98	7.06	9.13	11.34	11.67	12.41	14.13	15.39	15.70	15.81	15.84
1957	2.05	2.35	3.42	4.29	5.52	7.73	8.75	10.88	10.88	11.62	11.62	13.26
1958	1.44	3.28	5.26	6.67	8.65	9.58	10.33	12.11	13.80	15.07	16.12	16.95
1959	.20	1.21	1.60	2.53	3.13	3.52	4.02	4.82	4.90	4.90	5.40	5.90
1960	.34	.34	.68	1.25	3.36	4.97	5.50	7.60	7.60	7.65	7.70	8.14
1961	.28	1.87	3.73	3.99	5.56	6.27	6.41	--	--	--	--	--
29 year mean	.95	2.02	3.38	4.37	5.30	6.23	7.03	8.13	9.11	9.34	9.49	9.99
Susanville Airport												
1953	.14	1.21	4.60	8.32	8.40	9.43	10.22	11.93	12.43	13.39	13.49	13.70
1954	.63	2.10	2.16	4.75	7.22	8.91	9.31	9.34	9.94	9.94	9.94	10.19
1955	.16	1.38	4.03	4.85	5.53	6.05	6.65	6.82	7.62	7.64	7.64	8.36
1956	.35	.92	10.45	15.01	18.36	18.48	19.28	20.18	20.38	20.48	20.51	21.14
1957	2.85	3.12	3.71	6.59	9.68	10.79	11.70	13.13	13.34	13.40	13.40	14.68
1958	1.29	1.89	4.68	6.60	10.17	13.58	14.56	15.44	17.39	18.28	18.67	18.84
1959	.59	1.50	2.59	4.47	7.76	7.98	8.02	8.34	8.50	8.50	8.71	9.74
1960	.01	.01	.73	2.74	6.52	7.92	8.43	8.94	8.94	9.08	9.11	9.11
1961	.33	3.17	4.17	4.82	6.45	7.40	8.04	--	--	--	--	--
65 year mean	.90	2.53	5.36	7.87	10.20	11.76	12.61	13.46	14.15	14.31	14.39	14.69

1/ Station disactivated and then reactivated at slightly different relocation.

Table 7.--Bitterbrush seedling stocking on the various drill plantings[1/]

Experimental area and plot number		Growing season	Time of planting	Average stocking	Fiducial limits of stocking at 5 percent level
				- - Number of seedlings per acre --	
Hallelujah Jct.	1	1955	Fall	388	202- 614
Hallelujah Jct.	2	1955	Spring	212	73- 386
Red Rock	1	1955	Fall	366	191- 578
Red Rock	2	1955	Fall	655	370- 1,002
Red Rock	3	1955	Fall	1,025	637- 1,493
Red Rock	4	1955	Spring	117	42- 203
Red Rock	5	1955	Spring	1,106	760- 1,508
Dobie Flat	6A	1956	Fall	(2/)	--
Dobie Flat	6B	1956	Spring	6,532	5,696- 7,426
Mears Burn	20	1955	Spring	8,346	7,139- 9,648
Mears Burn	21A	1956	Fall	1/ 1,715	1,173- 2,349 1/
Mears Burn	21B	1956	Spring	1/ 5,272	3,860- 6,904 1/
Mears Burn	22A	1956	Fall	2,299	1,678- 3,018
Mears Burn	22B	1956	Spring	8,590	6,738-10,668
Doyle	3A	1956	Fall	(2/)	--
Doyle	3B	1956	Spring	1,995	1,538- 2,507
Flukey Well		1957	Spring	11,887	10,724-13,110
Mears	23	1958	Spring	1,920	1,403- 2,512
Dead Horse Canyon		1958	Spring	993	668- 1,372
Doyle	4	1958	Spring	(2/)	--
Casuse Mountain		1958	Spring	(2/)	--
Doyle	5	1958	Spring	(2/)	--
Doyle	6	1958	Spring	(2/)	--
Flukey Well		1960	Spring	3,000-5,000 (estimated)	--
Saddle Blanket Flat		1960	Spring	-	--
Doyle	7	1960	Spring	(2/)	--
Doyle	8	1961	Spring	349	183- 550
Cornell Rim		1961	Spring	976	784- 1,184

1/ Stocking estimated in the second growing season. All others estimated in first growing season.

2/ Trace.

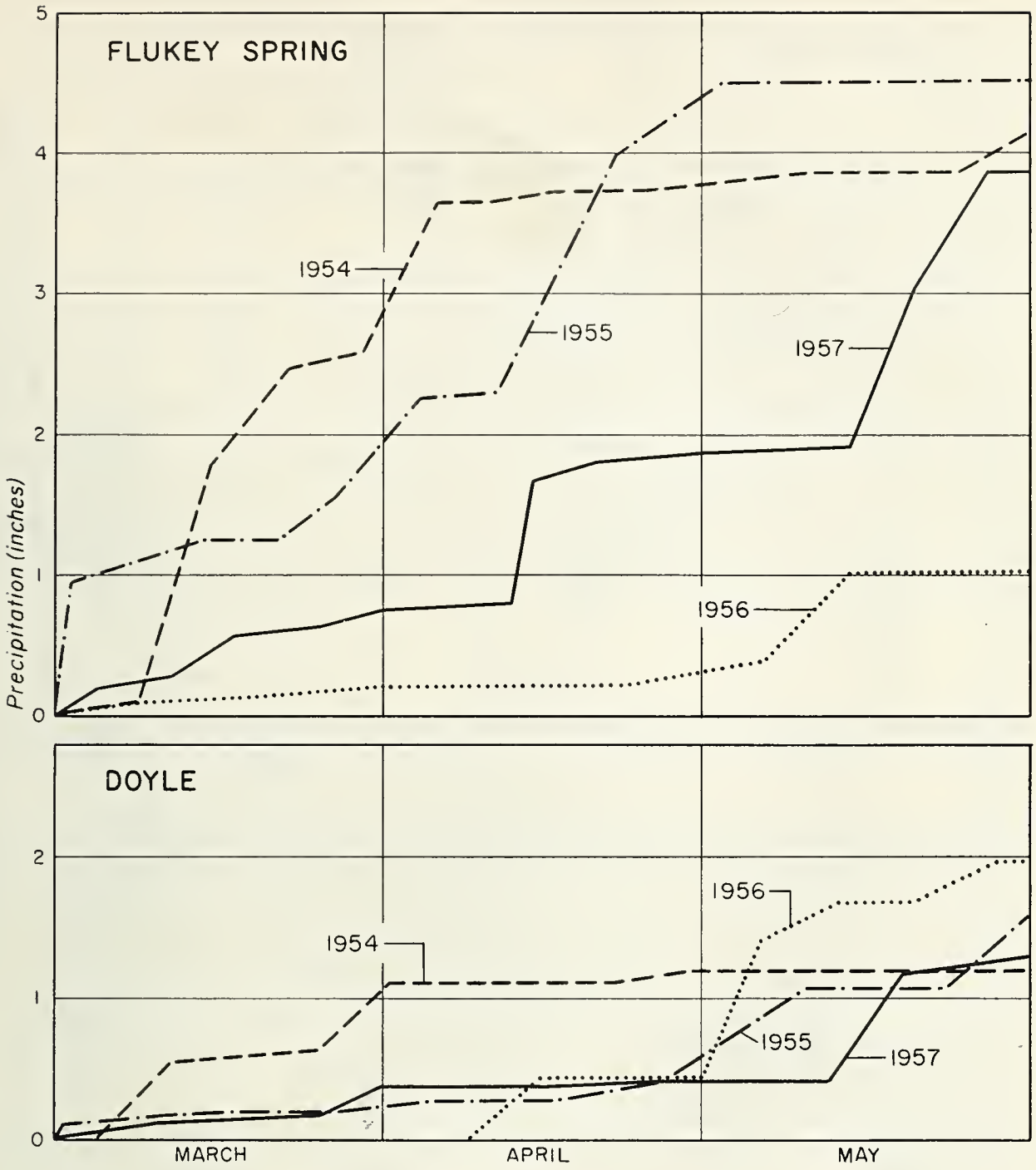

Figure 1.--Cumulative spring precipitation at the Flukey Spring and Doyle Experimental Areas; 1954-1957.

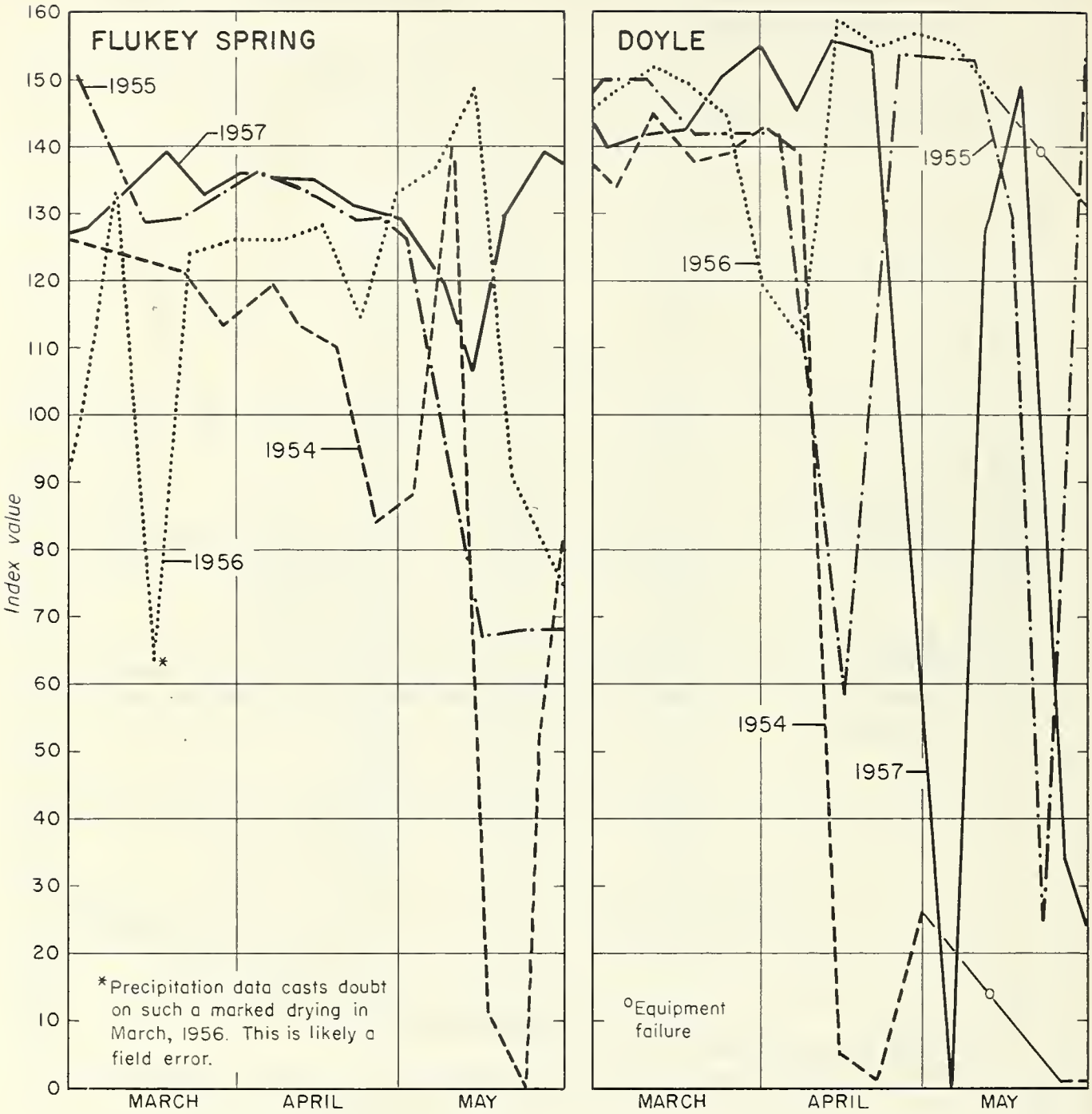

Figure 2.--Trends of soil moisture indices at 1.5 inch depths; 1954-1957. Indices of 120 to 150 are in the range of high soil moisture; 0 to 30, in the range of low soil moisture.

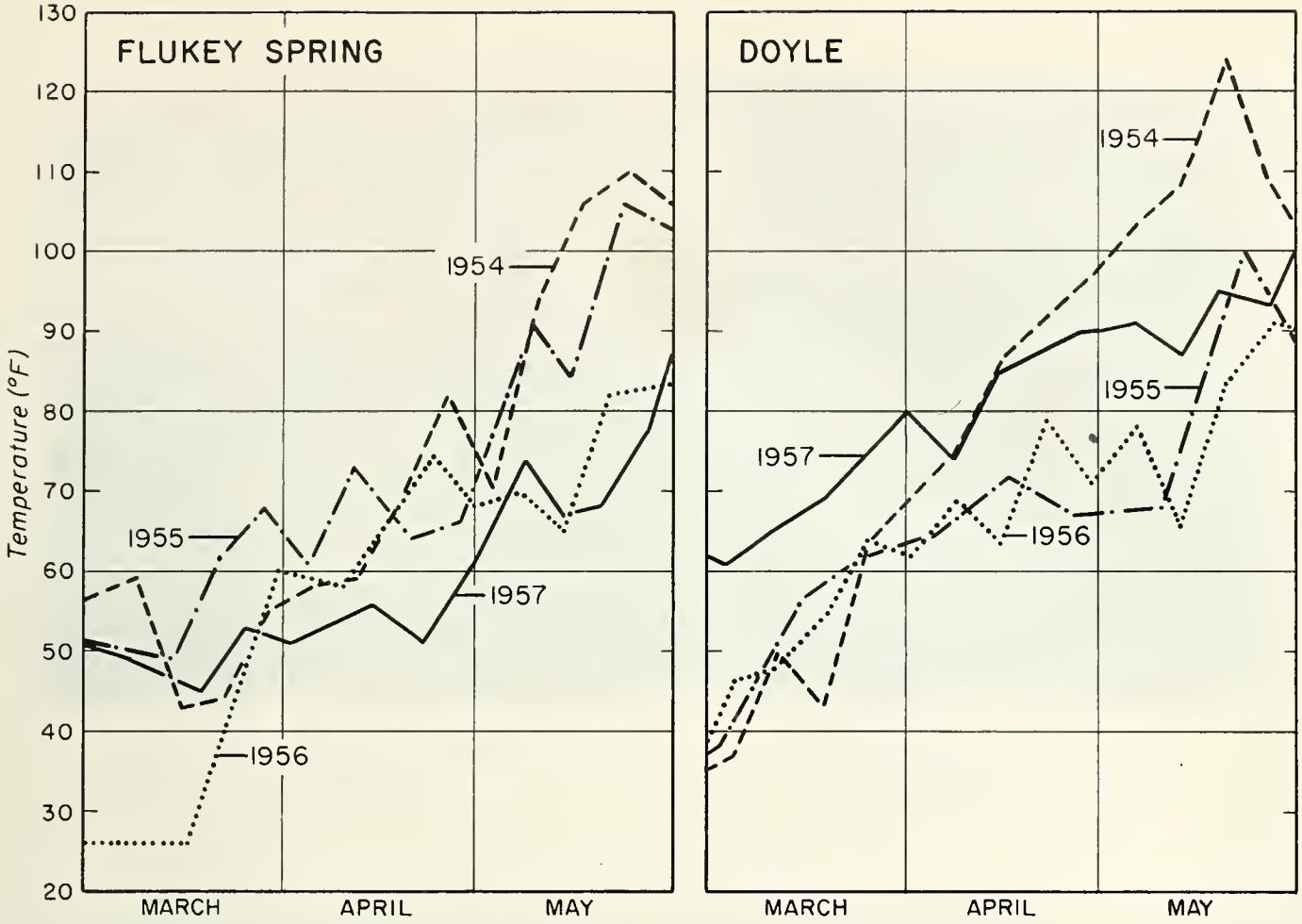

Figure 3.--Weekly average maximum soil temperatures at 1.5 inch depths; 1954-1957.

Flukey Spring

Doyle

Meadow View

Lava Beds National Monument - loam soil

Figure 4.--General views of study areas mentioned in this paper.

Lava Beds National Monument - pumice soil

Sheepwell Burn

Bolam Burn

Mears Burn

Figure 4.--Cont'd.

Casuse Mountain

Sage Flat

Red Rock

Dobie Flat

Figure 4.--Cont'd.

Dead Horse Canyon

Saddle Blanket Flat

Cornell Rim

Figure 4.--Cont'd.

Hubbard, Richard L., and Sanderson, H. Reed.
1961. When to plant bitterbrush--spring or fall? U.S. Forest Serv. Pacific Southwest Forest and Range Expt. Sta. Tech. Paper No. 64. 21 pp., illus.

For success in planting bitterbrush, the soil at planting depth must remain moist during germination and emergence. Fall-planted seed is in the ground ready to germinate as soon as the soil warms up. Emergence is usually 3 to 4 weeks later from spring planting. In tests in northeastern California spring plantings proved best where either or both of two conditions were met: precipitation was adequate and well distributed during the critical period and the soil retained moisture well. On drier sites or in very dry years on sites normally adapted to spring planting, fall planting was usually superior.

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